United States
Department of
Agriculture
Forest
Service
Southwestern
Region

Forest Pest Management Report

R-3 83-7

BIOLOGICAL EVALUATION
Pandora Moth

Kaibab National Forest
Arizona

January 1983

3430

R-3 83-7

BIOLOGICAL EVALUATION
Pandora Moth

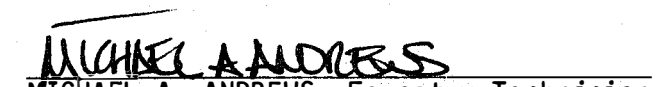
Kaibab National Forest
Arizona

January 1983

USDA Forest Service, Southwestern Region
State and Private Forestry
Forest Pest Management
517 Gold Avenue, SW
Albuquerque, NM 87102

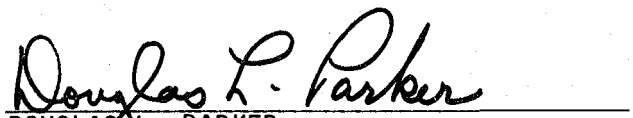
PREPARED BY:

DAYLE D. BENNETT, Entomologist
Forest Pest Management



MICHAEL A. ANDREWS, Forestry Technician
Forest Pest Management

APPROVED BY:



DOUGLAS L. PARKER
Director of Forest Pest Management

ABSTRACT

A biological evaluation was conducted by Forest Pest Management to assess and document losses to ponderosa pine throughout the current pandora moth, Coloradia pandora Blake, infestation near Jacob lake, Arizona, and to predict the extent and intensity of defoliation expected in 1983. The survey area covered about 45,000 acres of contiguous ponderosa pine and was divided into the following three strata: (1) Pine stands defoliated during two growing seasons; (2) pine stands defoliated during one growing season; and (3) pine stands showing no visible defoliation.

Mortality, regardless of cause, was at a low level and not significantly higher in those strata defoliated by pandora moth. Current and 1981 bark beetle attacks were infrequent (0.2 and 0.1 trees per acre, respectively) and found only in stratum 1. Western pine beetle, Dendroctonus brevicomis LeC., was the only primary bark beetle found during this survey.

Basal area growth was reduced 25 percent of normal due to pandora moth defoliation over the last 4 years in stratum 1. Defoliation within stratum 1 caused 15 percent more growth reduction in dwarf mistletoe-infected trees than in uninfected trees. No significant growth loss due to defoliation was detected in stratum 2.

Egg mass densities averaged 6.7 per branch in stratum 1, 13.5 per branch in stratum 2, and 5.5 per branch in stratum 3. These averages, about the same as those found during a similar survey in 1980 (7.6 egg masses per branch), indicate heavy defoliation may be expected again in 1983 over as much as 35,000 acres around Jacob Lake, Arizona.

Results of a virus survey indicate it unlikely a virus epizootic will cause a total collapse of the outbreak. However, virus rates will continue to increase and may have a regulatory effect on the pandora moth population by the time of pupation (late June), particularly in strata 1 and 2, where virus-induced mortality rates were relatively high--11.05 percent and 9.76 percent, respectively.

Management alternatives and recommendations are discussed in this report.

ACKNOWLEDGMENTS

We thank the following persons for their assistance in survey design and data collection, summarization, and analysis: Jerome Beatty, plant pathologist, Southwestern Region; Wayne Bousfield, entomologist, Northern Region; Mike Chavez, biological technician, Southwestern Region; Bob Eder, computer specialist, Northern Region; Richard Norris, biological technician, Southwestern Region; and John Schmid, entomologist, Rocky Mountain Forest and Range Experiment Station.

INTRODUCTION

A pandora moth, Coloradia pandora Blake, infestation, located near Jacob Lake, in northern Arizona (figure 1), was first noticed in August 1978 by a private citizen (K. S. Sanders, personal communication). During May and June 1979, 5,120 acres of ponderosa pine were severely defoliated by pandora moth larvae. In 1981, the area of defoliation had increased to about 19,000 acres, including the original 5,120 acres defoliated in 1979 (Bennett and Ragenovich 1982).

Because pandora moth infestations occur so infrequently--at about 20- to 30-year intervals--and usually collapse after 6 to 8 years, very little information is available concerning resultant growth loss and/or mortality due to repeated, heavy defoliation of pines during pandora moth outbreaks. Therefore, personnel from Forest Pest Management (FPM) conducted the following biological evaluation to assess and document losses to ponderosa pines throughout the currently infested area near Jacob Lake, and to predict the extent and intensity of defoliation expected in 1983. Objectives of this evaluation were to collect data to:

1. Determine if basal area growth loss or tree mortality has occurred to ponderosa pine as a result of: (1) One year of defoliation (1981) and/or (2) 2 years of defoliation (1979 and 1981).[1]

2. Determine if bark beetle-related mortality has increased within the defoliated areas.

3. Determine if basal area growth loss and/or tree mortality attributed to defoliation is significantly greater for dwarf mistletoe-infected trees.

4. Collect egg mass and virus data to predict the extent and intensity of defoliation in 1983.

METHODS

Data for this evaluation were collected September 21-30, 1982. The survey area covered about 45,000 acres of contiguous ponderosa pine type surrounding Jacob Lake, Arizona, and was divided into the following three strata (figure 2):

1. Pine stands defoliated during two growing seasons (1979 and 1981)--about 5,100 acres.

2. Pine stands defoliated during one growing season (1981)--about 19,000 acres.

---

[1] Pandora moth has a 2-year life cyle and feeding occurs in alternate years.

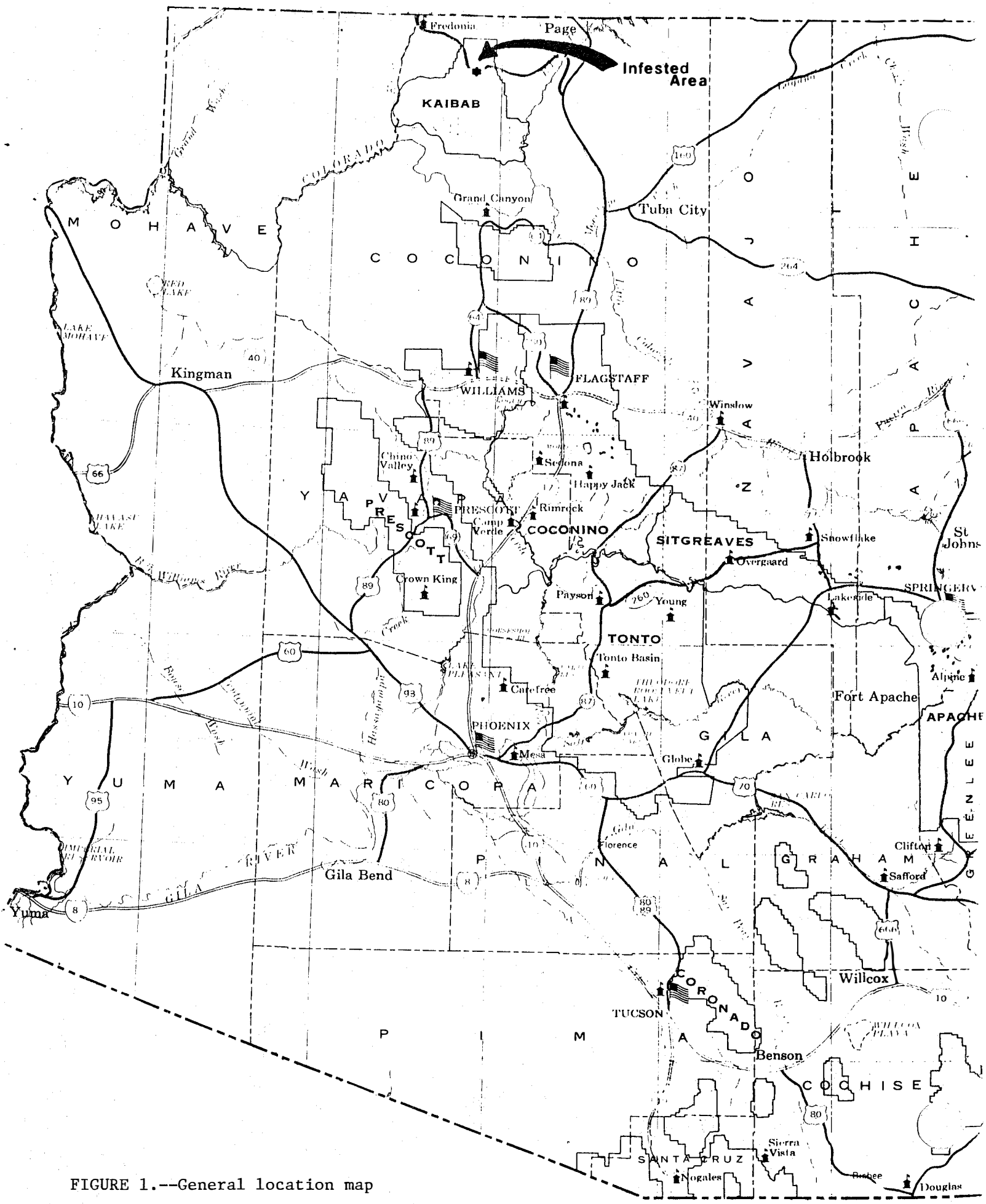
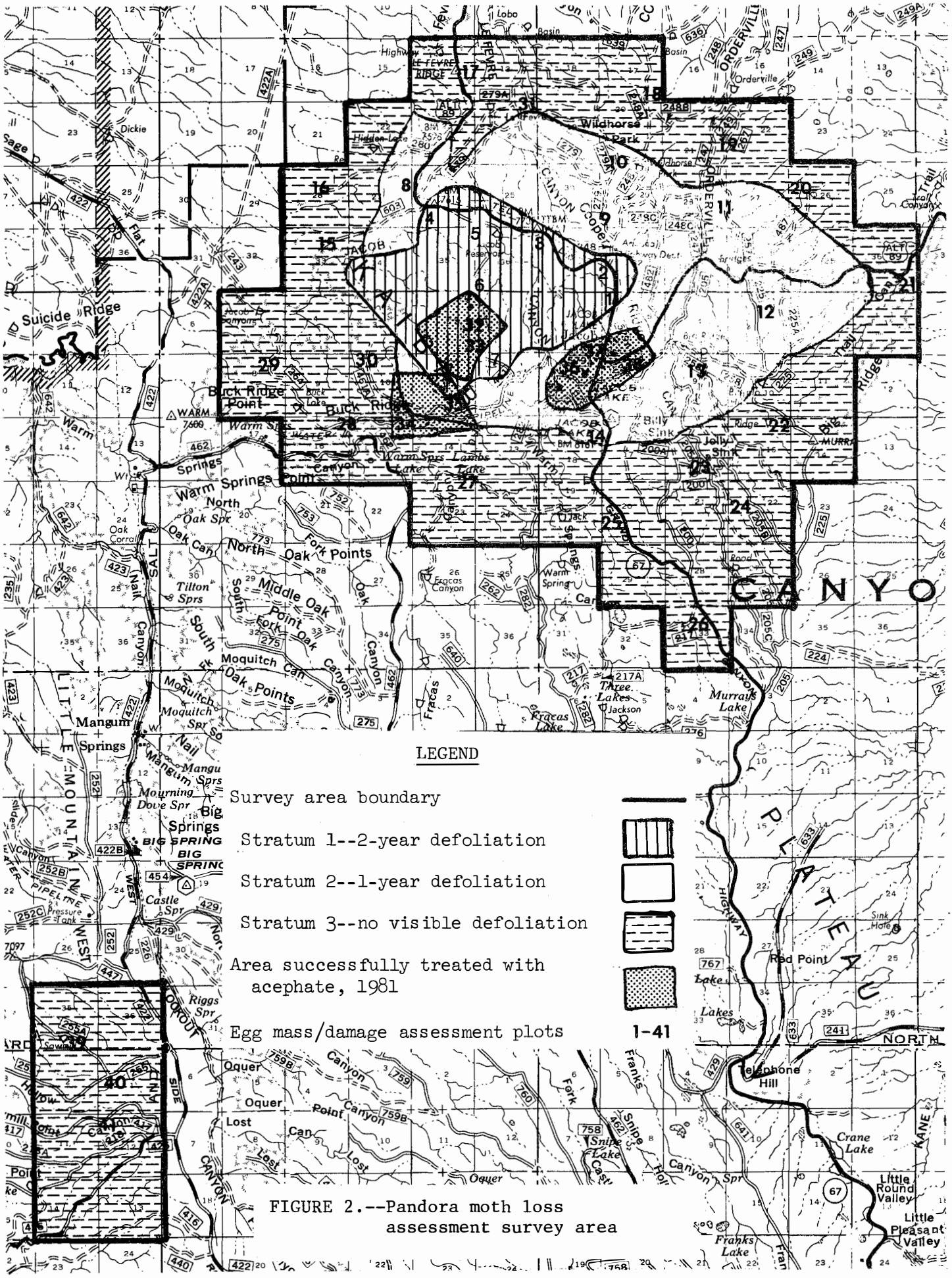


FIGURE 1.--General location map


LEGEND
Survey area boundary
Stratum 1--2-year defoliation
Stratum 2--1-year defoliation
Stratum 3--no visible defoliation
Area successfully treated with acephate, 1981
Egg mass/damage assessment plots
1-41
Wildhorse Park
Orderville
Suicide Ridge
Buck Ridge Point
Warm Springs
Mangum Springs
Big Springs
Red Point Lake
Telephone Hill
Crane Lake
Little Round Valley
Little Pleasant Valley
Franks Lake
Snipe Lake
Fracas Lake
Murrays Lake
Three Lakes
Jackson Lake
Lambs Lake
Jolly Sink
Billy Sink
Jacob Lake
Jacob Reservoir
Jacob Canyon
Canyon Cooper
Oquer Canyon
Oquer Point Canyon
Lost Can
Lost Canyon
Franks Canyon
Fork Franks Canyon
Snipe Canyon
Canyon Spr
Sink Hole
Dickie
Sage Flat
Lobo Basin
Fevre Ridge
Hidden Lake
Warm Spr
Lambs Lake
Warm Spgs Canyon
Warm Spgs Point
North Oak Spr
Oak Canyon
North Fork Oak Canyon
Middle Oak Canyon
South Fork Oak Canyon
Oak Points
Fork Points
Tilton Sprs
Oak Corral
Nail Canyon
Moquitch Can
Moquitch Spr
Mourning Dove Spr
Castle Spr
Riggs Spr
Pressure Tank
Sawmill
Jack Spgs
Warm Spring Can
Fracas Canyon
Sawmill Canyon
Lost Canyon
Point Canyon
Oquer Canyon
Fork Franks Canyon
Snipe Canyon
Canyon Spr
Sink Hole
Red Point Lake
Lakes

3. Pine stands of similar composition and location to stands in strata 1 and 2, but showing no visible defoliation in 1979 or 1981--about 26,000 acres.

Seven sample sites were located within each stratum (figure 2). No sample sites were located within areas successfully treated in a control project using acephate in 1981 (Bennett and Ragenovich). At each sample site, 5 variable plots (basal area factor 20) were systematically established at 5-chain intervals along a predetermined transect. These plots were numbered 1 to 7 in stratum 1, 8 to 14 in stratum 2, and 17 to 20, 22, 25, and 29 in stratum 3. This resulted in 35 sample plots per stratum. Tree species, diameter at breast height (d.b.h.), and damage class were recorded for all trees within each plot. Tree height, to the nearest foot, and radial growth measurements at d.b.h., to the nearest .01 inch (two cores per tree), were recorded from the first three live trees per plot. Radial growth measurements were obtained from the last 4 years' growth and the previous 4 years' growth in strata 1 and 3, and the last 2 years' growth, and the previous 2 years' growth in strata 2 and 3.

Regeneration data, including species, d.b.h., and damage class, were collected for all trees less than 5 inches d.b.h. from 1/300-acre fixed plots established at the center of each variable plot.

Forty-one egg mass plots were sampled throughout the survey area. Twenty-one of these plots were located at the first variable plot at each of the aforementioned sample sites and the remaining 20 plots were spaced throughout the survey area according to accessibility (figure 2). The relative density of egg masses was determined by cutting a 4- to 6-foot long branch from the lower half of the crown of five trees (20 to 40 feet tall) at each plot, counting all egg masses, and averaging the number of egg masses per branch. To reduce the variability between plots (personal communication with J. M. Schmid), we also counted and averaged the number of egg masses per first nine shoots.

A subsample of egg masses was collected and sent to Milt Stelzer, Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, where they were reared and analyzed for the prevalence of naturally occurring virus.

DATA ANALYSIS

Data collected from the variable and fixed plots were summarized and analyzed using a modified version of the computer program INDIDS (Bousfield 1980). An analysis of variance was used to compare stand characteristics, damage classes (except radial growth reduction), and egg mass and virus data between the three strata. Egg mass data were also compared with similar data collected in 1980 to estimate the extent and intensity of defoliation expected in 1983. Radial growth was converted to basal area increment then tested for differences between the strata using covariance analysis.

RESULTS AND DISCUSSION

Analysis of variance showed no significant difference at the 0.05 level between strata in either stand composition or damage classes, indicating a high degree of uniformity throughout the survey area. Sample errors for stand totals ranged from 9.9 to 12.1 percent basal area (BA), cubic feet volume per acre (CFA), and board feet volume per acre (BFA), indicating an acceptable degree of accuracy in our sample. The large sample error in trees per acre (23.0 to 43.3) was caused by a high degree of variation among and between the regeneration plots (trees less than 5 inches d.b.h.). Average stand composition by damage classes for each stratum is presented in table 1.

Mortality, regardless of cause, was at a low level and not significantly higher in those strata defoliated by pandora moth. Current and 1981 bark beetle attacks were infrequent (0.2 and 0.1 trees per acre, respectively) and found only in stratum 1. The only primary bark beetles found in the current and 1981 attacked trees were western pine beetles, Dendroctonus brevicomis LeC.

Analysis of covariance of the radial growth measurements (converted to change in basal area increment) showed 25 percent less than normal growth in basal area over the last 4 years in stratum 1 (table 2). This represents about 1.79 square feet per acre or 9,129 square feet within the stratum. No significant basal area growth loss occurred in stratum 2 (table 3). Also, by analysis of covariance, we determined that in stratum 1 pandora moth defoliation caused 15 percent more basal area growth reduction in dwarf mistletoe-infected trees than in noninfected trees (table 4). Dwarf mistletoe-infected trees in strata 2 and 3 showed no significant basal area growth loss, compared to uninfected trees within their respective stratum.

The average number of egg masses per plot and per stratum is shown in table 5. The averages in strata 1, 3, 1-treatment,[2] and 2-treatment[3] ranged from 5.5 to 7.8 and were not significantly different from each other. However, the average of stratum 2 was significantly greater, with an average of 13.51 egg masses per plot.

A total of 178 egg masses were collected and reared to determine virus prevalence. Larval emergence was recorded from 169 egg masses (94.9 percent), and egg parasites emerged from 9 egg masses (51.1 percent). Virus prevalence rates were calculated at 14, 21, and 28 days, and were 1.3, 2.2, and 5.2 percent, respectively. These rates were based on the rearing of 1,716 larvae. Table 5 shows the percent virus-induced mortality at 28 days by stratum. Stratum 3 had significantly less virus-induced mortality than strata 1 or 2.

From the results of this biological evaluation, we can conclude that, although some bark beetle activity has occurred in the area of 2-year pandora moth defoliation, the amount of resultant mortality was very

---

[2] Egg mass plots located within areas successfully treated with acephate in 1981 (Bennett and Ragenovich 1982).

[3] Ibid.

TABLE 1.--Average stand composition by damage class for strata 1, 2, and 3, pandora moth infestation, 1982

Stratum		Damage Class												Stand total	Percent standard error
		Undamaged	Bark beetle damage			Dwarf mistletoe rating[2]							Unknown mortality		
			Current attack	Last year's attack	Older attack	1	2	3	4	5	6	Total			
1	TA[1]	1,872.7	.2	.1	.6	12.0	2.2	2.2	4.6	1.8	3.6	26.4	.4	1,906.9	43.3
	BA	71.2	.6	.6	1.7	1.8	3.4	2.9	3.4	2.9	2.3	16.7	.6	92.4	10.3
	CFA	1,838.0	14.6	20.7	52.2	18.0	87.6	84.7	78.1	81.0	53.7	403.1	15.0	2,357.8	10.6
	BFA	8,915.5	76.2	122.4	279.7	45.4	425.0	406.5	285.9	401.9	188.7	1,753.3	69.1	11,216.2	11.7
2	TA	1,280.5	0	0	1.4	0	2.0	.7	1.2	1.5	.3	5.8	6.7	1,294.4	23.8
	BA	78.5	0	0	1.1	0	4.0	1.1	1.7	1.7	.6	9.1	2.9	91.7	9.9
	CFA	1,810.0	0	0	27.9	0	107.2	25.2	36.7	42.2	14.3	222.5	51.2	2,114.6	10.3
	BFA	8,603.5	0	0	132.6	0	594.8	126.2	172.3	186.4	72.4	1,152.1	138.7	10,027.0	11.2
3	TA	2,207.0	0	0	.7	1.0	.1	0	.2	0	0	1.3	0	2,209.0	23.0
	BA	92.8	0	0	1.7	2.3	.6	0	.6	0	0	3.4	0	98.0	11.2
	CFA	2,030.8	0	0	52.9	68.1	18.7	0	16.0	0	0	102.8	0	2,186.5	11.5
	BFA	9,806.5	0	0	307.3	387.8	119.2	0	93.8	0	0	600.9	0	10,714.7	12.1

[1] TA = Trees per acre
BA = Basal area
CFA = Cubic feet volume per acre
BFA = Board feet volume per acre

[2] Based on 6-class mistletoe rating system

TABLE 2.--Analysis of covariance comparing adjusted basal area growth for an equal period of time before and during the present pandora moth infestation in strata 1 and 3

Analysis of covariance								
					Adjusted			
Source	df	SSx	SP	SSy	df	$SS\hat{}_y$	$MS\hat{}_y$	$F_{.05}$
Among means	1	8.16	15.36	28.93	1	8.87	8.87	5.18
Within groups	12	29.99	21.21	33.82	11	18.82	1.71	
Total		38.15	36.57	62.75		27.69		

H_o: Adjusted growth means of stratum 1 and stratum 3 are equal.
Conclusion: Adjusted growth means of stratum 1 and stratum 3 are not equal.

Adjusted growth mean of stratum 1 = 5.37 square feet per acre.
Adjusted growth mean of stratum 3 = 7.16 square feet per acre.

$$\text{Percent growth loss} = \frac{\text{Adj. 3} - \text{Adj. 1}}{\text{Adj. 3}} \times 100 = 25 \text{ percent}$$

TABLE 3.--Analysis of covariance comparing adjusted basal area growth for an equal period of time before and during the present pandora moth infestation in strata 2 and 3

Analysis of covariance							
					Adjusted		
Source	df	SSx	SP	SSy	df	$SS\hat{}_y$	$MS\hat{}_y$	$F_{.05}$
Among means	1	1.34	1.68	2.11	1	.003	.003	.004
Within means	12	7.17	8.67	17.45	11	6.97	.63	
Total		8.51	10.35	19.56		6.97		

H_o: Adjusted growth means of stratum 2 and stratum 3 are equal.
Conclusion: Adjusted growth means of stratum 2 and stratum 3 are equal.

TABLE 4.--Analysis of covariance comparing adjusted basal area growth between dwarf mistletoe-infected and noninfected trees in stratum 1

Analysis of covariance								
					Adjusted			
Source	df	SSx	SP	SSy	df	$SS\hat{}_y$	$MS\hat{}_y$	$F_{.05}$
Among menas	1	2.20	3.02	4.14	1	1.12	1.12	10.76
Within means	8	28.00	17.64	11.65	7	.73	.10	
Total		30.20	20.66	15.79		1.85		

H_o: Adjusted growth means of dwarf mistletoe infected trees in stratum 1 are equal to adjusted growth means of uninfected trees in stratum 1.

Conclusion: Adjusted growth means of dwarf mistletoe-infected trees in stratum 1 are not equal to adjusted growth means of uninfected trees in stratum 1.

Adjusted growth means of dwarf mistletoe-infected trees in stratum 1 = 4.21 square feet per acre.
Adjusted growth means of uninfected trees in stratum 1 = 4.97 square feet per acre.

$$\text{Percent growth loss} = \frac{\text{Adj. uninfected} - \text{Adj. infected}}{\text{Adj. uninfected}} \times 100$$

$$= 15 \text{ percent}$$

TABLE 5.--Results of the 1982 pandora moth egg mass density and virus-induced mortality surveys, North Kaibab Ranger District, Kaibab National Forest, Arizona

Stratum[1]	Plot number	Ave. No. of egg masses per branch[2]	Ave. No. of egg masses per first 9 shoots[3]	Percent virus-induced mortality[4]	Predicted defoliation intensity[5]
1	1	6.0	3.4	27.45	Light
	2	8.0	5.8	2.08	Heavy
	3	5.0	2.6	21.74	Light
	4	6.6	3.8	0	Heavy
	5	3.2	2.8	0	Heavy
	6	12.4	4.8	0	Heavy
	7	5.6	2.0	26.09	Light
	$\bar{x}$	6.7	3.6	11.05	Moderate
2	8	15.4	8.8	1.96	Heavy
	9	12.4	7.0	47.37	Light
	10	26.6	13.6	6.90	Moderate
	11	14.6	7.8	0	Heavy
	12	13.2	6.8	0	Heavy
	13	2.0	1.4	2.86	Moderate
	14	10.4	6.8	9.26	Moderate
	$\bar{x}$	13.5	7.5	9.76	Moderate
3	15	4.6	2.4	0	Heavy
	16	8.0	5.4	0	Heavy
	17	5.0	3.4	0	Heavy
	18	12.2	8.6	0	Heavy
	19	11.2	6.0	0	Heavy
	20	9.0	5.8	0	Heavy
	21	.6	0	0	Light
	22	6.2	5.2	3.85	Moderate
	23	0	0	No collection	None
	24	6.6	2.0	0	Heavy
	25	5.8	3.2	0	Heavy
	26	1.4	.8	4.17	Light
	27	1.2	.8	0	Light
	28	4.6	2.4	0	Heavy
	29	10.2	3.4	0	Heavy
	30	8.8	3.6	1.89	Heavy
	31	5.4	4.4	0	Heavy
	39	3.4	1.0	0	Heavy
	40	3.6	2.4	0	Heavy
	41	2.0	1.0	0	Moderate
	$\bar{x}$	5.5	3.1	.52	Heavy
1-Treat	32	9.2	2.2	2.0	Heavy
	33	6.4	2.4	31.48	Light
	$\bar{x}$	7.8	2.3	16.74	Light
2-Treat	34	4.6	3.0	4.17	Heavy
	35	9.2	4.0	0	Heavy
	36	3.8	2.0	1.92	Heavy
	37	10.6	4.0	0	Heavy
	38	2.2	1.6	0	Light
	$\bar{x}$	6.1	2.9	1.22	Heavy

[1] Established prior to 1982 sampling as follows:
1 - 2 years' defoliation
2 - 1-year defoliation
3 - No defoliation
1-Treat - 2 years' defoliation; successfully treated with acephate
2-Treat - 1-year defoliation; successfully treated with acephate

[2] Branch length ranged from 93.8 to 157.2 cm; average for all plots was 123.8 cm.

[3] Found to be statistically more consistent (Schmid et al. 1983).

[4] Based on a subsample of egg masses.

[5] Based on egg mass density, percent virus-induced mortality, and professional judgment.

low and not significantly greater than that found in the areas of 1-year or no defoliation. Most bark beetle-caused mortality was attributed to western pine beetle which has caused similar low-level mortality on the North Kaibab Ranger District for the past several years. These beetles normally breed in overmature trees, in windfalls, in root-rotted trees, or in trees weakened by drought, stand stagnation, fires, and/or lightning strikes. Other causes of stress, such as dwarf mistletoe infections and repeated heavy defoliation by pandora moth, may predispose trees to attack by this beetle. However, no significant mortality has yet occurred and none is anticipated.

Basal area growth was reduced by 25 percent during the last 4 years in stratum 1. Similar losses can be expected in stratum 2 if defoliation occurs in 1983 and still higher losses are probable if subsequent defoliations occur. Furthermore, defoliation appears to cause greater losses in dwarf mistletoe-infected trees and stands; therefore, the greatest losses in the future should occur in stands and trees that have both dwarf mistletoe infections and 2 or more years of pandora moth defoliation. The magnitude of those losses depends upon both the spread and duration of the pandora moth infestation, and the distribution and intensity of dwarf mistletoe infection within the pandora moth infestation.

The average number of egg masses per plot for each stratum is equal to or greater than that found during a similar survey conducted in 1980 (Schmeckpeper). Therefore, heavy defoliation could occur over as much as 35,000 acres in 1983. Results of our virus survey indicate it unlikely a virus epizootic will develop throughout the entire infestation in time to reduce defoliation in 1983. However, we expect virus prevalence rates will increase as the larvae mature (May-June) and could have a regulatory effect on the pandora moth population by the time of pupation, particularly in strata 1 and 2 where virus induced mortality rates were relatively high (11.05 percent and 9.76 percent, respectively).

MANAGEMENT ALTERNATIVES

Maintain Present Management. With this approach, no action would be taken to suppress the pandora moth outbreak. Management programs would not be changed or delayed as a result of the outbreak. Adverse effects would include a temporary reduction in visual character of the landscape, annoyance of forest users when the caterpillars are present, temporary reduction in quality of wildlife habitat for some species, and growth loss in merchantable pine stands. We expect no significant mortality as a result of this infestation.

Direct Suppression. An aerial application of the chemical insecticide acephate at the rate of 0.75 pound active ingredient per acre could be done in an effort to suppress the entire outbreak during late spring of 1983. Tree damages prior to treatment would be accepted and would reduce the benefits of treatment, but further, more serious losses may be prevented. Visual quality of the landscape, as well as quality of wildlife habitat, would be maintained. Annoyance of forest users by

caterpillars would be reduced. Cost of an aerial application of acephate would be about $10 per acre, and adverse environmental effects would be minimal and temporary.

Treatment of Selected Areas. Selected areas, where the defoliation of trees and the presence of caterpillars is considered unacceptable, could be treated with an aerial application of acephate to reduce both the adverse effects of defoliation and the density of caterpillars. This alternative would have the same effects as those discussed in the direct suppression alternative, but they would apply only to those areas selected for treatment. Treatment cost would be about $10 per acre, but total cost would be much less than that for direct suppression of the entire infestation.

RECOMMENDATION

We recommend no action over most of the infestation. Defoliation may continue for one or more larval cycles; however, we expect the infestation to eventually collapse due to natural factors, with minimal resultant losses.

In select areas, where defoliation of trees and the high density of caterpillars may be unacceptable, such as Jacob Lake Lodge and nearby campgrounds, we recommend an aerial application of acephate. To be most effective, treatment should be carried out as soon as larvae resume active feeding (in early May); and application should not be attempted if precipitation is likely within 2 days following treatment (Bennett and Ragenovich 1982).

LITERATURE CITED

Bennett, Dayle D., and Iral R. Ragenovich. A pilot control project to evaluate acephate for control of pandora moth, Coloradia pandora Blake (Lepidoptera: Saturniidae), Jacob Lake, Arizona, 1981. USDA Forest Serv., Southwestern Region. R-3 82-10. 36 pp.

Bousfield, Wayne E. 1980. Region 1 forest insect and disease survey system. USDA Forest Serv., State and Private Forestry, Missoula, Mont. 23 pp.

Graham, Donald P. 1979. Pandora moth in ponderosa pine--North Kaibab Ranger District. USDA Forest Serv., Southwestern Region, lett., biol. evaluation. 2 pp.

Schmeckpeper, Thomas G. 1980. Pandora moth--North Kaibab Ranger District. USDA Forest Serv., Southwestern Region, lett. biol. evaluation. 6 pp.